Impact of Subsurface Temperature Variability on Meteorological Variability: An AGCM Study

Authors

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Abstract

Anomalous atmospheric conditions can lead to surface temperature anomalies, which in turn can lead to temperature anomalies deep in the soil. The deep soil temperature (and the associated ground heat content) has significant memory -- the dissipation of a temperature anomaly may take weeks to months -- and thus deep soil temperature may contribute to the low frequency variability of energy and water variables elsewhere in the system. The memory may even provide some skill to subseasonal and seasonal forecasts.

This study uses three long-term AGCM experiments to isolate the contribution of deep soil temperature variability to variability elsewhere in the climate system. The first experiment consists of a standard ensemble of AMIP-type simulations, simulations in which the deep soil temperature variable is allowed to interact with the rest of the system. In the second experiment, the coupling of the deep soil temperature to the rest of the climate system is disabled -- at each grid cell, the local climatological seasonal cycle of deep soil temperature (as determined from the first experiment) is prescribed. Finally, a climatological seasonal cycle of sea surface temperature (SST) was prescribed in the third experiment. Together, the three experiments allow us to isolate the contributions of variable SSTs, interactive deep soil temperature, and chaotic atmospheric dynamics to meteorological variability.

The results show that allowing an interactive deep soil temperature does indeed significantly increase surface air temperature variability. An interactive deep soil temperature, however, reduces the variability of the hydrological cycle (evaporation and precipitation), largely because it allows for a negative feedback between evaporation and temperature.

Popular Summary

Deep soil layer has a higher heat capacity than the Earth's surface layer (by a factor of about 70) which prolongs the deep soil temperature response to the surface temperature changes. Thus, the heat capacity in the deep soil layer plays a critical role in understanding the inter-connection between colder-than-normal winter temperatures and subsequent spring temperatures or warmer-than-normal summer temperatures and subsequent fall temperatures. Given the complexity of the interwoven climate processes in nature, for e.g., surface temperature variability is directly associated with both the surface latent heat flux and the deep soil temperature, the heat capacity in the deep soil layer may also have important implications to the hydrological cycle (evaporation/precipitation). In this study, a physics based global climate simulation model was used to investigate the impact of subsurface heat content to the model's surface air and precipitation variability.

Because dearth of decades-long observation records of meteorological variables for long-term analysis, the use of models to study the global climate variability is popular among the climate scientists. Moreover, the models can be handy tools in such analysis because models allow manipulate key parameters or variables to test the required climate scenario. This study uses three long-term global climate simulations to isolate the contribution of deep soil temperature variability to variability elsewhere in the climate system -- model deep soil temperature was used as a measure of the heat content in the subsurface layer. The first control (CTL) experiment consists of a standard climate ensemble simulation in which the deep soil temperature variable is allowed to interact with the rest of the system. In the second experiment, the coupling of the deep soil temperature to the rest of the climate system is disabled -- at each grid cell, the local climatological seasonal cycle of deep soil temperature (as determined from the CTL experiment) is prescribed. Finally, a climatological seasonal cycle of sea surface temperature (SST) was prescribed in the third experiment. Together, the three experiments allow us to isolate the contributions of variable SSTs, interactive deep soil temperature, and chaotic atmospheric dynamics to meteorological variability.

The results show that allowing an interactive deep soil temperature does indeed significantly increase surface air temperature variability. The strongest impact was seen in the winter simulation through out the northern--hemisphere. An interactive deep soil temperature, however, reduces the variability of the hydrological cycle (evaporation and precipitation), largely because it allows for a negative feedback between evaporation and temperature.